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VERTICAL CUTOFF RIGIDITY AND THE INTENSITY DISTRIBUTION OF COSMIC RAYS NEAR CAPE TOWN.

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A fairly sharp increase of 2.3% in the intensity of the nucleonic component of cosmic rays was observed at 30 000 feet pressure altitude along a contour of constant calculated vertical cutoff rigidity on a research flight from Cape Town, South Africa, at 18°E longitude, to a point 2°W longitude. The increase seems to be an inherent feature of this region near the South Atlantic geomagnetic anomaly. Detailed cutoff rigidity calculations in vertical and inclined directions revealed that the observed increase may at least partly be ascribed to variation in effective cutoff rigidities along the route. However, the increase could also be attributed, at least as far as morphology is concerned, to the continuous precipitation in a restricted area of those high energy inner radiation belt protons that have short live-times.

Introduction and results

A survey of cosmic ray intensities at aircraft altitudes was carried out near Southern Africa during September 1976. The nucleonic component of the cosmic rays was recorded by a standard 1-NM-64 neutron monitor aboard a South African Air Force C 130 transport plane. Counts were recorded for 4 minute 40 second intervals, each with a 20 second read-out. Position fixes of the aircraft were obtained halfhourly or more frequently, and the pressure altitude was constant to within 50 feet of a specified height. Only results obtained at a pressure altitude of 30 000 feet are used in this analysis.

Flight routes are depicted in Figure 1 as are lines of constant vertical cutoff rigidity which were deduced from the 5° by 15° world grid of vertical cutoff rigidities calculated by Shea and Smart (1975) for 1975. The count rates on Flights 2 and 3 towards the west of Cape Town and back, and from Cape Town to Port Elizabeth, are also plotted as a function of longitude. In Figure 2 the count rates of Flights 1 and 4 towards Cape Town from the north and towards Port Elizabeth from the south are plotted as a function of vertical cutoff rigidity. A mismatch is apparent, with the count rates for the south-bound flight higher than the count rates which would have been expected on the basis of the results for the north-bound flight.

The purpose of the flight towards the west was to determine the influence, if any, of the South Atlantic geomagnetic anomaly on cosmic rays as observed at 309 g cm^{-2}. The count rates on the outbound and inbound legs of this flight, i.e. along contours of approximately constant vertical cutoff rigidities of 4.6 GV and 5.0 GV respectively, were adjusted to the count rates to be expected along the 4.8 GV contour, by using the average slope of the latitude effect at 4.8 GV from Figure 2, ignoring the last three points on the south-bound leg to Cape Town. A significant increase in count rates is observed in Figure 3 near the western extremity of Flight 2, which could not be traced to changes in pressure altitude. The vertical cutoff rigidity should have

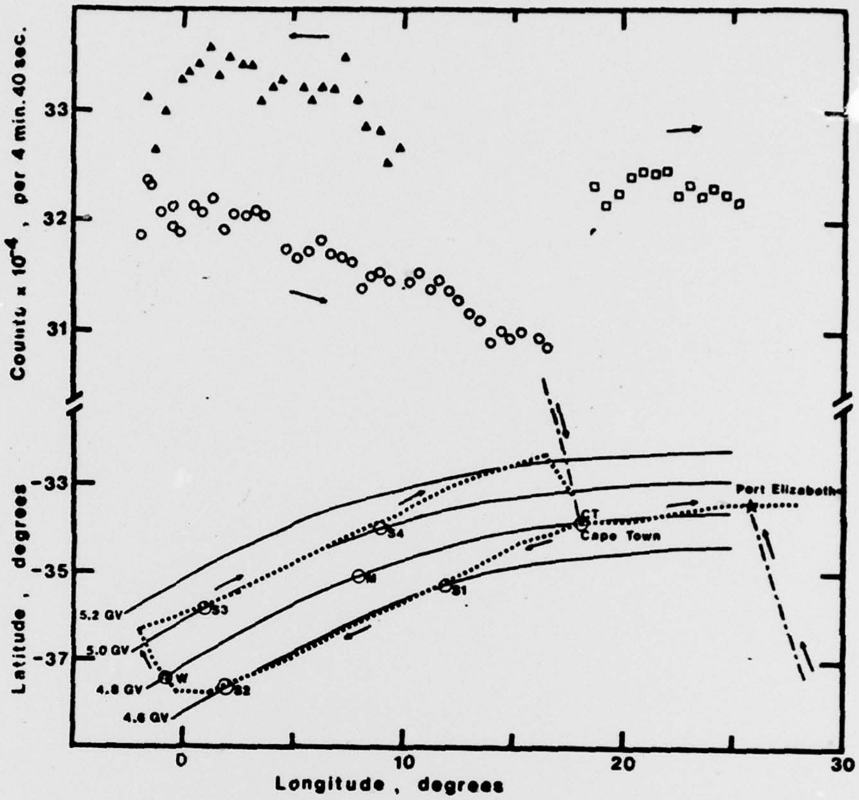

Figure 1. Routes of aircraft flights(dashed), lines of constant calculated vertical cutoff rigidity (solid) and count rates for the flight towards the west.

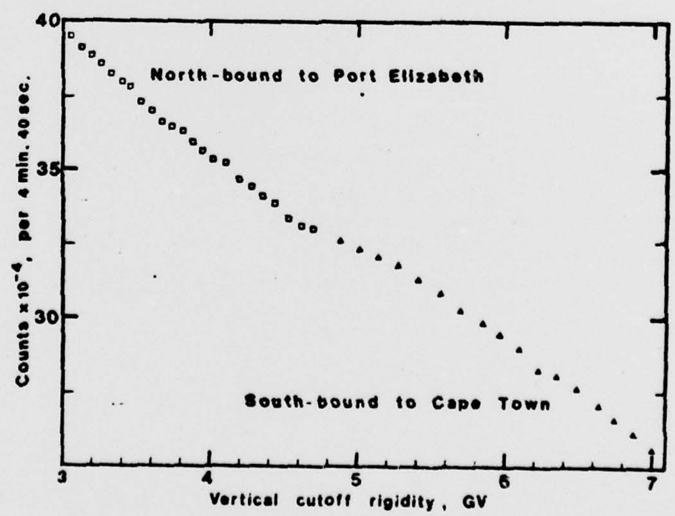

Figure 2

been 0.18 GV lower at the western extremity than at Cape Town to account for this increase. The count rates of the 9-NM-64 neutron monitor at Hermanus, South Africa, gave no indication that changes in the count rates during the period of the flights could be attributed to changes in the primary cosmic ray spectrum, except for a gradual increase of 0.2% per hour during the period of Flight 3.

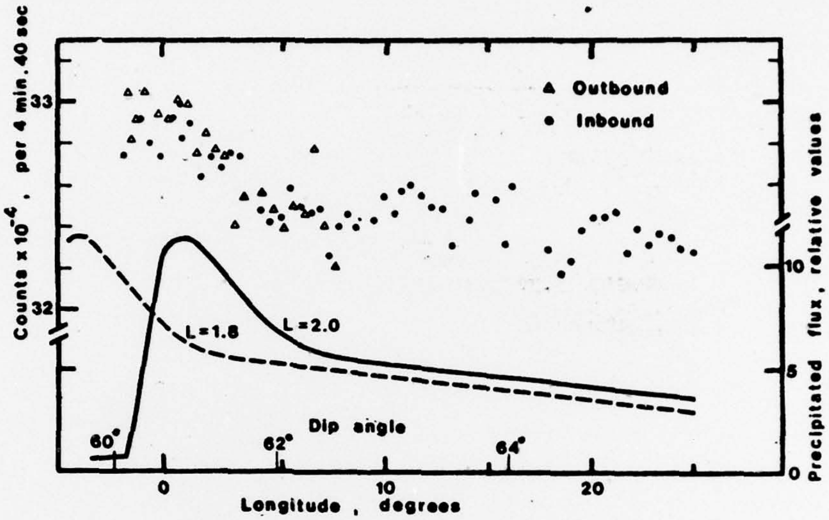

Figure 3 : Count rates adjusted to the contour of a constant vertical cutoff rigidity of 4.8 GV. Magnetic dip angle and the predictions of Torr are also indicated.

2. Discussion

From Figures 2 and 3 it is apparent that the values of vertical cutoff rigidities obtained by interpolation from the 5° by 15° grid are not consistent with the data obtained at aircraft altitudes in this region. To determine whether systematic errors in interpolation method, or differences in cutoff rigidities in inclined directions, could cause the increase observed on the flight towards the west, a number of detailed cutoff rigidity calculations were performed by the trajectory-tracing method (Shea et al.,1976) for some locations, as indicated in Figure 1. The results of these calculations appear in Tables 1 and 2.

Table 1

	S1	S2	S3	S4	CT	M	W
Geographic latitude	-35.25	-37.64	-35.85	-33.90	-33.90	-35.12	-37.45
Geographic longitude	12.00	2.00	1.00	9.00	18.40	8.00	- 0.83
Vertical cutoff rigidity,GV	4.67	4.51	5.02	5.03	4.82	-	4.79

From Table 1 and the known latitudinal variation it follows that a 2.3% increase in count rate on the outbound leg of the flight may be explained by the 0.16GV decrease in vertical cutoff rigidity from 4.67GV to 4.51 GV for the two points S1 and S2 in Figure 1. However, the same can neither be said of the points S3 and S4 on the return leg, nor for the points CT and W on the 4.8 GV contour. The co-authors found that generally penumbra effects could account for changes of between 0.05GV and 0.1GV in vertical cutoff rigidities between two closely-spaced points. However,if cut-off rigidities were integrated over

a large solid angle, these effects would be minimized.

Table 2 Inclined-direction cutoff rigidities, in GV.

Zenith angle		Azimuth angle, clockwise from geomagnetic north. 0	45	90	135	180	225	270	315
45°	CT	4.72	5.21	5.63	5.61	4.90	4.39	4.03	4.21
	M	4.69	5.24	5.59	5.50	4.88	4.37	4.09	4.31
	W	4.77	5.25	5.52	5.24	4.77	4.18	4.06	4.26
60°	CT	4.50	5.18	5.86	5.84	5.01	4.21	3.87	3.98
	M	4.59	5.33	5.78	5.69	4.97	4.30	3.96	4.03
	W	4.50	5.32	5.66	5.50	4.69	4.07	3.89	4.14
75°	CT	4.41	5.22	6.24	8.05*	6.84*	4.08	3.82	3.87
	M	4.43	5.31	5.97	7.89*	6.77*	4.15	3.92	3.96
	W	4.66	5.34	5.83	8.61*	7.19*	4.04	3.86	3.97

*Influenced by the earth shadow effect.

Secular changes in the geomagnetic field from 1975.0 to 1976.7, and the change in angle between the earth-centered vertical direction and the geomagnetic vertical direction from Cape Town to the western turning point, were ruled out by the co-authors. The sum of these effects could contribute a 0.02 GV reduction in vertical cutoff rigidity near the western extremity of the flight.

The difference in cutoff rigidity between the points CT and W was obtained for every direction from Table 2, also for those directions influenced by the shadow effect. It was found that changes in these cutoff rigidities in inclined directions would result in a mean reduction in cutoff rigidity of 0.02 GV per direction between CT and W, a value much too small to account for the increase. The dip angle of the geomagnetic field is anomalously high in South Africa, and changes rapidly towards the west, as indicated in Figure 3 for the route of the flight. A systematic change in inclined-direction cutoff rigidity is observed in the values of Table 2. For zenith angles of 45° and 60°, the cutoff rigidities for azimuth angles between 270° and 45° are lower at W than at CT, but higher for azimuth angles between 90° and 225°. The pattern for a zenith angle of 75° is contaminated by the shadow effect and the loop-cone phenomenon (Cooke and Humble, 1970). The above-mentioned effects would be caused by the 4° change in dip angle from CT to W. The shadow effect and the loop-cone phenomenon would be sensitive to changes in dip angle, and to the value of the magnetic declination used in the calculations. Detailed tracing of the shadow cone along the 4.8 GV contour should be carried out to determine its effect on effective cutoff rigidities. It is, however, difficult to see how even a large change in cutoff rigidities due to main cone folding could cause a further mean reduction of approximately 0.1 GV per direction to completely explain the intensity increase, in view of the small solid angle applicable to this effect.

It thus appears possible that the observed longitude effect may be attributed to changes in effective cutoff rigidity, but then only if all the effects considered add together in the correct direction.

Another cause for the increase should be considered, i.e. precipitation of high energy protons from the L = 1.8 shell of the inner radiation belt. These protons are produced mainly by energetic albedo neutrons in the magnetosphere. Those protons produced on a given L-shell with pitch angles slightly smaller

than the local critical pitch angle for stable trapping, would drift towards the west with continually lowering mirror height as these particles approach the South Atlantic geomagnetic anomaly, to precipitate in the centre, or towards the east, of the anomaly. One would thus expect an increase in proton fluxes in the upper atmosphere with longitude from the east towards the anomaly for a given L-value. Furthermore, those 'stably-trapped' protons produced from CRAND neutrons with energies sufficiently high for their motion to be only approximately adiabatic, would suffer pitch angle diffusion after repeated mirroring (Garmire, 1963), and would also eventually precipitate at, or slightly eastward of, the position of minimum mirroring height. For $L = 1.8$ the maximum energy for adiabatic motion (and thus stable trapping) seems to be $E_p \lesssim 500$ MeV. Protons with energies larger than 500 MeV, or their genetically related neutrons, would be detectable at aircraft altitudes, even though they would be incident from the south and west with zenith angles $\gtrsim 60^{\circ}$ (König and Stoker 1975).

Torr et al.(1976) developed a model for the longitudinal extent of the directly precipitating particle flux as a function of L-value, with an isotropic input source of particles. Their prediction for the energy-independent (up to the adiabatic limit) flux of precipitated protons as a function of longitude is depicted in Figure 3 for $L = 2$. The same curve is also plotted with a 5° shift in longitude towards the west to give an indication of their prediction for $L = 1.8$. If the increase in count rate could be ascribed solely to continuous precipitation of high energy inner radiation belt protons, the experimental observations indicate an easterly shift of about 2° in the longitude of maximum precipitation for $L = 1.8$.

3. Conclusions

The observed increase towards the geomagnetic anomaly could at least partly be ascribed to a reduction in effective cutoff rigidity. A flux of nucleons, originating from high-energy protons precipitating continuously from the inner radiation belt, would also be present at aircraft altitudes in the same area. The question remains whether the flux of these particles would be high enough to cause the increase.

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A fairly sharp increase of 2.3% in the intensity of the nucleonic component of cosmic rays was observed at 30,000 feet pressure altitude along a contour of constant calculated vertical cutoff rigidity on a research flight from Cape Town, South Africa, at 18°E longitude, to a point 2°W longitude. The increase seems to be an inherent feature of this region near the South Atlantic geomagnetic anomaly. Detailed cutoff rigidity calculations in vertical and inclined directions revealed that the observed increase may at least partly be ascribed to variation in effective cutoff rigidities along the route. However, the increase could also be next page

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